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CELL-DOCTRINE

IN THE

LIGHT OF RECENT INVESTIGATIONS.

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C. HEITZMANN, M. D.,

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THE CELL-DOCTRINE IN THE LIGHT OF RECENT INVESTIGATIONS.[1]

The subject of my discourse is living or organized matter, that substance which builds up plants as well as animals, the simplest infusorium as well as the most highly developed mammal. The facts which I am about to explain are destined to throw light on many physiological and morbid processes, to assist the physician in the diagnosis and prognosis of different diseases, and perhaps even to direct his therapeutical action.

The question, what living matter really is, cannot yet be answered from a chemical standpoint, and there is reason to doubt whether it ever will be settled, inasmuch as it is impossible to obtain pure living matter in a quantity sufficient for chemical analysis. In every substance the living matter must necessarily be composed of minute particles, which can never be seen, even with the highest magnifying powers, i. e., the simplest units, the so-called molecules, which admit of no further division. After Elsberg's at present almost universally-adopted denomination, we shall term the molecules

[1] Read before the County Medical Society of New York, January 22, 1877.

of the living matter "plastidules." Molecules, again, are composed of simple elementary atoms, the quantity and nature of which give the essential character to every substance. While the molecules of inorganic bodies are formed by relatively few atoms—water-molecules, for instance, being built up of one atom of oxygen and one atom of hydrogen—we know that the plastidules are much more complicated in their atomistic construction. Every plastidule is formed by at least five elements, namely: 52 to 55 per cent. carbon, 21 to 23 per cent. oxygen, 15 to 17 per cent. nitrogen, 6 to 7 per cent. hydrogen, and 1 to 2 per cent. sulphur. The nature of the union of these elements is a very complicated one in every plastidule, but not as yet elucidated. We generally call the organic substances simply proteinates or albuminates, comprehending by these terms both the living matter and its derivations or products.

While chemical examination has revealed very little of the intimate nature of living matter, we know certain properties to be essential to living matter as long as it is really alive, and we know also some of its morphological features.

These properties are mainly two: motion, and the capability of producing its own kind. In speaking of the motion of living matter, we do not mean the motions to which every substance is subject, and of which light, heat, electricity, etc., are peculiar manifestations; but there are certain forms of motion dependent on the contractility or irritability of living matter which do not occur in inorganic bodies, nor in organic matter after it has ceased to be alive. The motion is of two varieties: one leading to changes of shape, the other to changes of place—locomotion. Both kinds are due to a peculiar structure of the living matter in a certain stage of its development, and will occupy us afterward. Here I will only mention that, in former times, locomotion was considered as a characteristic quality of animals. To-day we are fully aware that a great many of the low forms of vegetable life in different stages of development are endowed with locomotion, apparently depending on a certain degree of individual will.

The property of producing its own kind is exclusively

possessed by living matter, and is also of two varieties, viz.: production for the benefit of the individual itself, with the result of increase of size—growth; and production of new individuals—generation. We know that every living body is originally very small; the ovum of the largest animal is just perceptible to the naked eye, but it increases by taking up nourishing material from without—it grows. After having reached a certain size it does not grow larger, but only reproduces the used-up material, until at last it ceases to produce anything, and then becomes what we term dead, and thereupon is subject to chemical laws of decomposition, which means simplification of its atomic construction. To-day, scientists have arrived at the conviction that the building-material of plants cannot be essentially different from that of animals. With advancing knowledge of natural philosophy, the boundaries between the animal and vegetable kingdoms have more and more faded away. It is impossible, in many cases, to say exactly at which point of development an organism is certainly a plant or an animal. Huxley is of the opinion that the only distinguishing character between plants and animals is that the former feed on simple or elementary inorganic material, while the latter take in organized food; but this opinion can hardly be maintained, inasmuch as it is impossible to say how the lowest forms of animals are nourished at all. We know, moreover, through Charles Darwin's researches, that there are carnivorous plants.

The property of generation may be looked upon, in accordance with E. Haeckel's definition, as a growth of the individual beyond its individual limits; at least, every organism must reach a certain degree of development before it is fit for propagation. This property is so characteristic for living matter that Lady Montagu, having been taught by a philosopher that every organism is a mechanical apparatus, raised the question whether he ever saw, when putting two watches together, a third one resulting from it. It is known that among the lowest forms of organisms propagation takes place without sexual intercourse, whereas there is a division of labor among the higher organisms, both vegetable and animal: in the former case, one individual gives rise to a new one; in

the latter, two individuals (male and female) are required to produce a third. It is known, furthermore, that the simplest form of propagation is division, when one individual, after having increased in size, splits into two organisms of smaller size. A variety of this process is the "gemmation," e. g., a small bud, growing from the surface of the mother-body, becomes gradually pedunculated, and at length separates by breaking of the pedicle, and forms a new individual. Another variety is the "endogenous formation," in which a lump originates and grows within the mother-body, and is freed afterward through bursting or active perforation of the mother. Essentially all these processes are the same, and the main form of propagation is always a division. Even in the most highly-developed mammals the embryo originally forms a part of the mother-body, and, after having grown, by internal gemmation or endogenous production, up to a certain size, separates from the vehicle, the womb, and represents a new individual.

There are certain peculiarities about generation which I beg leave briefly to explain. I mean the resemblance of the newly-formed body to the producing organisms, the parents. It is an easy matter to understand that both individuals will be alike in a case of simple division, because both formerly made one single body; but how shall we explain the remarkable fact that, in higher animals, the offspring so closely resembles the progenitors, though only very minute parts of these—the ovum and the spermatozoids—contributed to give rise to a new individual?

The opinion of E. Hering, of Prague, that organized matter is endowed universally with an "unconscious memory," a function upon which depends, besides the capacity of imagination, of thinking, of habit, also nutrition and propagation, is not an available one. I therefore take into consideration only the three modern hypotheses, of Charles Darwin, Louis Elsberg, and Ernst Haeckel. Charles Darwin promulgated in 1868 the "Provisional Hypothesis of Pangenesis," which consists essentially in the assumption that through all stages of development the living cells or units of the body throw off small granules, or "gemmules," which accumulate to form

the sexual elements, and all the cells of the body, therefore, participate indirectly in the new formation of organisms. In 1872 Elsberg published his theory of the "Regeneration or Preservation of the Plastidules." He lays down the proposition that the germ of every living individual contains plastidules of all its ancestors ; so that these are bodily regenerated in their offspring, simply because bodily particles are preserved directly from generation to generation. In 1875 Haeckel announced the hypothesis of the "Perigenesis of the Plastidules," according to which, in opposition to the opinions of Darwin and Elsberg, no regeneration or preservation and transmission of plastidules take place, but only a transmission of motion through inheritance.

Among these theories I confess that that of Elsberg seems to me the most probable one, inasmuch as it tries to explain why certain properties of ancestors, even in the second or third generation, may reappear ; why bodily and mental peculiarities are directly transmitted from parents and grandparents to their offspring. With this theory, which suggests a direct increase of plastidules within a limited bulk of living matter, we may readily understand why, with progressive development of a species, a perfection takes place which leads to the production of more and more advanced beings from relatively lower ancestors. Haeckel's view can scarcely be supported so long as we know that a change of motion as function is always due to a material cause, namely, change of molecules in quality and quantity. All this is speculation only, though entirely legitimate as an attempt to bridge over precipices which present insurmountable obstacles to the passage of our intellect.

Let us advance now toward the study of the shape of living matter, a study in which excellent investigators have been engaged during the last forty years.

In 1835 Dujardin discovered a contractile substance common to low animals, which he termed "sarcode," but he was far from the knowledge that this substance exists in all animals, believing it to be peculiar to the lowest forms. After Schleiden, of Jena, in 1838 discovered the form-elements of plants, and proposed for them the name of "cells," Theodor

Schwann, of Berlin, in 1839 found a striking analogy between the intimate structure of vegetable and animal organisms, and asserted that the "cells" are the simplest constituent parts of all tissues of the animal body as well as of the plant. In his opinion each cell is a vesicle composed of a transparent membrane, containing a fluid in which is suspended a central solid body, the nucleus. Schwann believed that cells may originate in a substance, the plasma, independently of former cells, and through the authority of Johannes Müller, of Berlin, who fully accepted Schwann's doctrine, this became the leading one, so that even C. Rokitansky, of Vienna, held at first that the plasma of the blood may, under favorable circumstances, produce cells. It was the discovery of Rudolph Virchow, in 1852, that the cells are really the seats of life, and that every cell must originate from a former cell: *Omnis cellula e cellula.* Virchow, however, still adheres to Schwann's original idea as to the construction of cells, although a very simple consideration will show that this cannot be correct, viz., the consideration of the fact that no living material is ever a fluid, but always either a solid or a jelly-like, semifluid substance. The next who advanced the cell-doctrine was Max Schultze, of Bonn. He showed in 1861 that changes of form, locomo, tion, and division, are impossible to corpuscles surrounded by a resistant membrane; he maintained that the smallest individual elements of organisms are lumps of a jelly-like matter endowed with life, for which he proposed, for good reasons, in accordance with the German botanist Hugo von Mohl, the term "protoplasm." This jelly-like substance is identical with Dujardin's "sarcode." Max Schultze was the first to announce that the living matter of the infusion-animalcules and that of the cells of all animals are one and the same substance. The cell consists, according to this observer's views, of a minute particle of protoplasm, in which there are imbedded the nucleus and granules. In the same year (1861) E. Brücke, of Vienna, though accepting Max Schultze's views asserted that the nucleus is not an essential part of the cell, as he knew of many living lumps without any nucleus. Brücke defined the "cell," for which he also proposed the name of "elementary organism," to be a structureless lump of proto-

plasm; though fully aware of the necessity of the existence of some structure, as in every substance, he regarded the structure of the cell as imperceptible to our senses. S. Stricker, in accordance with Brücke, in 1868 explained that the cell is nothing but a particle of structureless protoplasm, usually containing granules, but that these granules are not essential characteristics. He especially examined the form-elements of the ovula of frogs while studying their development, and observed in these elements hyaline flaps, which he took for pure protoplasm, whereas the greater part of the protoplasm was filled with granules or particles of yolk. The fact that every living lump is capable of taking in foreign minute corpuscles, granules of carmine or aniline for instance, from without, led him to the conclusion that protoplasm is devoid of any visible structure, while the visible granules are secondary products of the protoplasm or foreign substances accidentally taken into the interior of the protoplasmic lump. S. Stricker in his "Histology" discusses the question, "how large the lump of protoplasm must be to be entitled to the name of 'cell,'" and comes to the conclusion that we should call a living corpuscle a "cell" only when we perceive in it the properties of a living organism, viz., growth, motion, and reproduction. In 1862 Lionel Beale, of London, accepted Max Schultze's doctrine and the term "protoplasm," arriving, however, at conclusions quite different from those of German biologists. Apparently his microscopes, although magnifying very much, did not show him the details within the protoplasm, and thus, judging especially from carmine staining, he asserted the nucleus to be living or "germinal" matter, while a great deal of protoplasm was to him identical with the basis substance of connective tissue, and he termed this the "formed material," designating by this term even the most active tissues, the muscles, and nerves.

This was the state of the cell-doctrine when I took up its study in Vienna in 1872. After having observed certain peculiarities in various protoplasmic bodies, I endeavored to investigate the condition of living matter in so-called infusions, and I may say that in this I was successful.

If we place some black earth and green blades of grass,

in some Croton water, in a soup-plate, and allow this infusion to stand undisturbed in a light room at ordinary temperature, we shall always succeed in raising new organisms, so-called infusoria. There are different ways of making an infusion: for instance, we may simply infuse some hay or chicken's food in water; but I prefer the method mentioned, on account of the certainty of its producing important low forms of animalcules.

Strange to say, but it is a fact, that if we mix together some inorganic material, earth and water, with organized bodies, such as grass, apparently destined to decay, there will sprout up a remarkably rich generation both of plants and animals. To explain this fact is quite difficult. Some observers believe that the decaying particles of vegetables themselves change into new organisms under favorable circumstances; while others, and doubtless the majority, are of the opinion that there are floating in the air millions of invisible germs of plants and animals, which, on finding a favorable soil for development, begin to grow and prosper. The germ-theory, first thoroughly established by Pasteur, has not as yet been contradicted in a satisfactory manner; we have, therefore, every reason still to adhere to it. Certainly no development of infusoria takes place if the air be prevented from reaching the infusion.

It is very remarkable that I succeeded in raising almost identical forms of living organisms on mixing together the same material several thousand miles away from New York, viz., in Vienna. There is a slight difference, however, important enough to be mentioned. In Vienna I never saw an amœba without a distinct lump in its interior, the nucleus; while in New York the more common occurrences are amœbæ without nuclei. As these animalcules are identical in every other respect both in Vienna and New York, this fact disproves the opinion of many histologists that the nucleus is something essential to the so-called "unicellular" organism. Haeckel's view, viz., that there is a marked difference between forms devoid of a nucleus, termed by him "cytodes," and those with nuclei, termed "cells," must be considered to be untenable.

Let us take from the infusion, best from the sides of the

plate, a drop; place it on a slide, cover it with a thin covering-glass, and examine it carefully with a high magnifying power, of about one thousand, with a good immersion-lens. On the first or second day after making the infusion we do not succeed in discovering any organism in it, unless such were already present on the torn grass. About the third day we see a number of very minute granules, just perceptible to the highest powers of the microscope; these granules are yellowish, shining, and motionless. One day afterward, besides such small granules there are seen very many somewhat larger ones, which in their interior show a central hole, inclosed on all sides by a yellowish, shining substance. That this is the case can be proved by adding a drop of water, whereupon the granules turn and always present the same aspect. The cavities in the interior of the shining lumps, apparently filled with some fluid, differ in their refracting power from the surrounding mass; they show a slight rosy color and bear the name of "vacuoles" in histology. A vacuole is the first sign of a differentiation within the lump, though the latter is still immovable.

One day later we see, besides the forms already described, somewhat larger, round granules with several vacuoles, some granules looking as if perforated by vacuoles, like a sieve; the differentiation between the two substances within the lump—the yellowish, shining, and the colorless, rosy refracting one—has apparently advanced. On the fourth or fifth day we have before us a certain number of small living plants and animalcules. Among these let us choose a lump, which, looked at with a magnifying power of about five hundred, has already shown us wonderful changes of shape after a few minutes' rest, due perhaps to the shock of the transport from the plate to the slide. Such a minute transparent corpuscle, floating in the water of the infusion, constantly changes its outlines, by throwing out offshoots or processes, mostly in the form of hyaline flaps. We are sure we have an amœba before us.

The best species for our examination is the common *Amœba diffluens*, which slowly moves in one direction by protrusion of single flaps; the star-like and giant amœbæ are less fit for

close examination, both on account of their rapid and complicated changes and their limited viability. With a magnifying power of five hundred we recognize in the nucleated amœba a shining lump, viz., the nucleus; around this a small, light seam, not uniform during the motion of the lump; and minute grayish or yellowish granules, scattered throughout the transparent mass. The floating amœba throws out offshoots in all directions, and retracts them again; it therefore changes its shape, but does not move away. Presently we observe, by careful handling of the screw of the microscope, that one of the processes reaches the surface of the covering-glass or of the slide, and at the next moment the floating ceases and creeping begins. The amœba protrudes, on one side of its body, a hyaline flap, while on the opposite side an apparent accumulation of the granules takes place; shortly afterward the granules are again uniformly distributed, and the whole lump is dragged toward the point of the protruded hyaline flap.

Let us now adjust the immersion-lens. We recognize in the centre of the body the apparently solid or vacuolized, roundish nucleus, and this surrounded by a narrow, transparent seam. The latter is traversed by very delicate, slender, conical, grayish threads, of which the thicker ends emanate from the nucleus, and the points are attached to the nearest granules, scattered in the body of the amœba. Many of these granules are connected with each other by slender threads, and are thus in direct communication with the denser stratum circumscribing the amœba. In this way a delicate network is formed, with nodules, represented by the nucleus and the granules. Whenever a hyaline flap is being protruded, there appears on the opposite side of the body an approximation of the granules to each other, and a perceptible enlargement of the same; in the protruded flap itself the granules, on the contrary, become smaller and separate from each other until all structure disappears from our view, and the flap represents a homogeneous mass. After having reached a certain size, the flap again presents the above-mentioned structure, and the granules float toward the protruded point, and drag with them the nucleus, which itself never shows active change of shape or motion. The locomotion of the amœba is thus accomplished.

At the next moment the same spectacle is seen again and again, perhaps for an hour, until the movements become slower, and at last we have before us an immovable round body, when the amœba is dead.

During the movements of the amœba vacuoles not unfrequently make their appearance within the body. Every vacuole appears to be lined by a thin, shining, continuous layer, analogous to the layer which surrounds the whole body. Sometimes floating granules can be observed within the vacuole, which by turning around change their places and now and then throw out delicate threads; occasionally some of these threads reach the wall of the vacuole, then the latter suddenly disappears and the network is reëstablished. Such changes in vacuoles are frequently observed in the body of another infusion-animalcule, the shooting cyclidium, and also of human colorless blood-corpuscles.

By adding a drop of distilled water to the preparation we succeed in making the amœba swell up, whereupon most of the granules, apparently torn apart, jump about very actively in the interior of the body. By adding a drop of glycerine, on the contrary, the amœba is suddenly contracted, and forms a small, almost homogeneous lump. If we substitute water for the glycerine, the amœba always changes into a granular globule, in which the original structure is again plainly visible, though the globule is motionless and apparently dead.

The changes in the infusion just described allow the conclusion that living matter appears at first in the form of a small granule only; gradually through differentiation becomes a vacuolized body, in which it forms a framework, and is at last arranged as a network; the latter state being that of common protoplasm. As one and the same granule cannot be followed up in its gradual development in the infusion, we must look for other living corpuscles, to see these changes directly. Such corpuscles are those suspended in the blood of the common fresh-water crawfish (*Astacus fluviat*).

For examination of the blood, we prepare the covering-glass by greasing its edges on one surface with olive-oil. If we break off the leg of the living animal, fresh from the river, a drop of the colorless blood will ooze out, which being caught

on the slide, and covered with the oiled covering-glass, remains unchanged, as the evaporation of the plasma is prevented. No other preparation than that for producing a so-called "moist chamber" in the simple way mentioned is required for the examination of the blood of cold-blooded animals.

Immediately after placing the blood upon the slide, most of the blood-corpuscles look coarsely granular, viz., are filled with shining, yellowish, round granules. Shortly afterward every granule begins to enlarge and flatten; so much so, that by mutual accommodation the granules become polyhedral, being separated from each other by small hyaline seams, which are traversed by very distinct, grayish, intersecting threads. Soon every flattened granule is provided with one or two vacuoles; the yellowish substance surrounding the vacuoles suddenly commingles with the same substance of neighboring granules, and, as if bursting, is transformed into a delicate, finely-granular network, in the midst of which a formerly invisible nucleus can be seen. The nucleus remains immovable, while the body, now pale and finely granular, still changes its shape.

In the blood-corpuscles of crawfish, therefore, the changes of the granules, from originally solid, homogeneous bodies into vacuolized ones, and at last into a delicate network, can be seen directly in the course of about half an hour. The body resulting from the changes of the granules of the blood-corpuscle is analogous in every respect to the amœba.

Colorless blood-corpuscles of the newt (*Triton*, *Salamandra*) and the frog can also be used for the study of the structure of the protoplasm with a very satisfactory result. By cutting off with scissors the point of the tail of a newt, or a toe of a frog, we are enabled to transport a drop of blood directly to the slide, and by covering the drop with a thin glass, oiled on its edges, we obtain admirable specimens for examination even with the highest powers. The finely-granular, colorless blood-corpuscles of the newt show, at the common temperature, continuous changes of shape and place by projecting a great number of delicate offshoots in all directions, and again retracting them. During this time the grayish or yellowish network in the interior of the body is also

constantly changing in shape. Very often vacuoles appear in the body, and sometimes the body looks as if perforated by vacuoles, like a sieve. In such a body the identity of the framework surrounding the vacuoles, and of the network inclosing hyaline spaces of varying sizes, can easily be proved; at all events, the body reveals a sponge-like structure. Excellent subjects for watching the structure with high powers are also the colorless blood-corpuscles of frogs.

Blood-corpuscles of mammals and of man must be examined on a heated stage, in order to raise the temperature of the specimen to that of the body. The specimen is easily obtained by pricking the palmar surface of the hand. At the common temperature of the room no structure is recognizable in my own colorless blood-corpuscles, but the structure becomes the plainer the more the temperature of the stage approaches the normal heat of the body. There appear one or two grayish, homogeneous lumps in the interior of the corpuscle, and from the periphery of the lumps many conical, slender, grayish threads emanate, which unite with other threads and form at their points of intersection somewhat thickened nodules, or granules, the whole constituting a complete, grayish network throughout the corpuscle. A continuous grayish layer circumscribes the periphery of the corpuscle, in close connection with the most external threads. While the temperature rises slowly, continuous changes in the shape of the network and of the whole corpuscle take place; but locomotion occurs only if the specimen has been inclosed between two thin glasses, which furnish the corpuscles with points of fixation. Distinct nuclei, with nucleoli, all united by means of grayish threads, appear only when the motion of the corpuscles becomes slow, or when the corpuscles approach the state of rest, viz., that of death.

In colostrum-corpuscles, present in milk during the first days after delivery, the network is also plainly visible; many of the granules are here changed into shining fat-globules, but are still in connection with their unaltered neighbors. Later on, all the granules of the colostrum-corpuscles appear to be transformed into fat-globules.

The blood-corpuscles of the crab, and especially those of

the oyster, are also excellent for studying the structure of protoplasm. If we break the shell of an oyster and cut the animal, we may bring its colorless blood under the microscope and watch the structure of the blood-corpuscles, and their striking changes of shape, and even their locomotion. We always see before us organisms entirely identical with different forms of amœba.

Lastly, I may mention that products of inflammation, pus-corpuscles, as long as they are alive, show exactly the same structure and capability of creeping as are visible in an amœba; the latter fact having been discovered about ten years ago by Von Recklinghausen, of Strasburg. All the elements of the body, including those of the tissues, agree with the amœba in respect to their structure and viability.

Before advancing in my discourse, I wish to say a word in regard to the correctness of my assertions, inasmuch as obser vations of so delicate a nature, with high magnifying powers, have always been liable to error.

There are two ways of satisfying one's self of the correctness of a microscopical interpretation: demonstration to others who are unprejudiced and impartial observers, and representation independent of our senses, viz., by photographs. Both means have been adopted with the discovery of the structure of protoplasm. Dr. L. Elsberg, who spent several months in examining the protoplasmic bodies in my laboratory, arrived at the conviction that my views are correct, and announced this conviction in the "Transactions of the American Medical Association" in 1875. Dr. Elsberg is of opinion, in which I agree with him, that no preliminary studies in microscopical science are required for seeing the intimate structure of the living elements. An unprejudiced observer, with a practice of a few days, will be able to satisfy himself in regard to matters which have been overlooked by many experienced microscopists, apparently because of their prejudices or belief in assertions of authorities. Besides Dr. Elsberg, many gentlemen, and also a lady, have satisfied themselves of the truth of the structure of protoplasm during the courses of instruction in histology which I have given in my laboratory for two years. Dr. J. J. Woodward, of Washington, has published

beautiful photographic plates of cancer-specimens, made with oxycalcium-light, with relatively low powers, and on these plates the structure of the protoplasm is plainly visible to the naked eye, wherever the elements lie in a correct focus. The objection that this structure might perhaps be due to coagulation, to changes after death, falls to the ground, as on looking at photographs of living blood-corpuscles, such as have been produced by Dr. Cutter, of Boston, the network is as plainly visible as in the plates of Dr. Woodward. Doubtless the photographs of living and creeping amœbæ would give the same result.

Those, however, who are delighted with nice staining of microscopic specimens, splendid projections on screens, and large micro-photographs, generally lose sight of the aim of the science of microscopy. We have other things to do than to play with methods of staining and projections. We have to study the relations of physiological and morbid appearances to their anatomical bases—a more serious and difficult task. Photographing microscopical specimens has reached its highest perfection in this country, where technical talent is so remarkably developed. Although such photographs are useful in certain respects, their value should not be over-estimated, because they are indistinct wherever the specimen is not even or shows several strata. Under such circumstances photographs can hardly replace drawings made by an experienced and conscientious artist.

Let us proceed now to the consideration of the structure of protoplasm as explained schematically. Judging from the observations in an infusion, or in blood-corpuscles of crawfish, it is plain that living organisms originally form homogeneous lumps. These, with advancing growth, are differentiated by the formation of vacuoles into a framework, and finally into a network. In both latter states we distinguish two substances, one identical in every respect with the substance forming the first homogeneous lump, the other contained in the vacuoles and in the meshes of the fully-developed protoplasmic body. The substance forming the framework and afterward the network is endowed with the properties of contractility, and—as it originated from a small lump—

growth; therefore it is living matter. On the other hand, the substance contained in vacuoles, and in the meshes of living matter, never presents signs of life, being a fluid. That it is not pure water is proved by the phenomena of diffusion on adding a drop of water to the specimen. The solid nucleolus, the solid nucleus, the granules, their uniting threads, and the surrounding layer of the whole body, are formations of living, contractile matter, which are suspended in a non-living fluid; i. e., the network contains in its meshes and incloses as a shell on the surface of the corpuscle, and also in a hollow nucleus, a non-contractile fluid. The fully-developed protoplasmic body, therefore, is constructed like a sponge, but, at the same time, inclosed on all sides by the same substance which forms the trabeculæ of the sponge—the trabeculæ and the shell being the living matter.

An analysis of the observations of the living protoplasmic body teaches us that there can be distinguished mainly three different appearances of the net-like living matter, namely, that of rest, that of active contraction, and that of passive extension.

In the state of rest, as seen in a motionless amœba, or immediately after death, the granules are almost uniformly distributed throughout the protoplasm, united with each other by slender threads, the bridges of living matter. (*See* Fig. 1.)

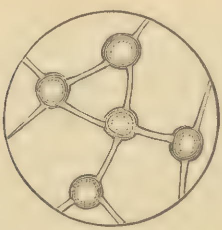

FIG. 1.

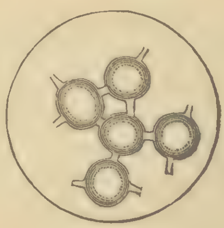

FIG. 2.

In contraction we observe an enlargement of the granules by shortening of their uniting threads and approximation to each other. (*See* Fig. 2.) Nothing has been added to the living matter and nothing lost from it; only the distribution of the plastidules has changed, leading to the narrowing of

the network and a partial expulsion of the fluid formerly contained in its meshes. Contraction is the active property of living matter, and on it are based the simple change of shape and the locomotion of the whole organism.

Extension depends upon a decrease of size of the granules, with a removal from each other and an elongation of the uniting threads at the expense of the bulk of the granules, even to the disappearance of all structure. (*See* Fig. 3.) The exten-

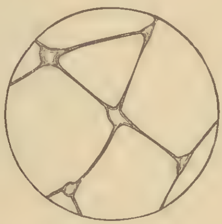

Fig. 3.

sion takes place in a passive manner; the fluid contained in the meshes of the living matter is pushed out toward the periphery, and there leads to the formation of a protruding offshoot—the hyaline flap. At the beginning of the protrusion we still observe in the flap the presence of structure, while at the highest point of extension the structure can no longer be seen, because granules and threads have been elongated to their utmost capability. We may compare this phenomenon to the extension of glass rods melted on a flame until the threads become so thin as to disappear to the naked eye.

These three states of living matter explain to us not only the movement of a simple protoplasmic lump, but also the action of the most highly-developed muscles, which, as I have demonstrated, are entirely identical in their structure with the simple amœba. Were the amœba a sponge without an inclosing layer of living matter on its surface, every contraction would lead to an escape of the fluid, and no locomotion would be possible; the presence of an outer, although very thin, layer of living matter is necessary to the various movements of living protoplasmic bodies.

By adding a drop of glycerine to the creeping amœba, or

to any protoplasmic body, we can bring about a fourth state of living matter, viz., the highest degree of contraction, for which S. Stricker and I have proposed the term "tetanus." The fluid of the protoplasm being suddenly extracted by the glycerine, all granules flow together, forming a structureless lump of much smaller size than that of the original corpuscle, without visible limits of the single granules. (*See* Fig 4.)

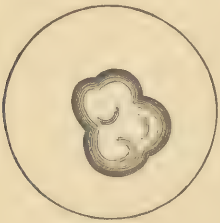

Fig. 4.

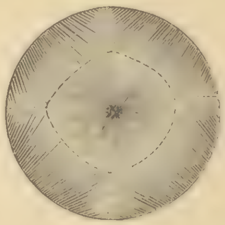

Fig. 5.

As mentioned before, a rehabilitation of the former net-like structure is produced by taking away the glycerine and adding water, without reëstablishment of motion.

All these changes of living matter can be directly seen under the microscope. But we cannot observe the formation of a flat, extended layer at the boundaries of the whole body, at those of a hollow nucleus and of every vacuole. I therefore had to have recourse to the hypothesis that a granule may send out offshoots in great number, leading to the disappearance of the central mass, and that these offshoots, melted together, may produce a continuous layer. (*See* Fig. 5.) By the union of many such areas an extensive layer could be produced, large enough to cover in the whole protoplasmic body.

The presence of a layer of living substance on the outer surface of the body explains to us why every protoplasmic lump can so easily take up foreign bodies, and why vacuoles can form and disappear almost suddenly. We must imagine that the living matter is capable of entering any of the described states at any time, so that a flat layer, for instance, may immediately change into a network, and *vice versa*. When the lump swells up through the addition of water, the

granules are torn apart and float freely in the fluid, as occurs in swelled amœbæ and saliva-corpuscles. The breaking of the outer shell, with escape of minute particles of the amœba, still endowed with life, and the process of the division, can also easily be understood.

Let us now draw conclusions from the observations described.

Protoplasm is not structureless, but has a very distinct net-like structure. The protoplasm, forming a so-called "cell," possesses a very complicated structure, and therefore the cell, in the sense of M. Schultze and E. Brücke, is not an elementary organism. As stated above, every particle or granule of living matter, very many of which go to build up a protoplasmic lump, is endowed with all the properties of the so-called "cell"—growth and motion. The question is, How large must be a simple particle of living matter to entitle it to the name of an individual organism?

In the infusion we see growing granules, just perceptible to the highest magnifying powers of the microscope, in a fluid where there were none a short time before. S. Stricker, when examining the renowned Lostorfer's corpuscles, which for a short period of time were thought to be characteristic of syphilis, made observations analogous to those which I have described. He saw extremely small granules originate in the plasma of the blood of persons broken down by different diseases; the granules, which were first just perceptible, grew under the eyes of the observer, and, after having reached a certain size, divided into two parts, producing new individuals. Moreover, we know of minute organisms in decomposing organic tissues—the micrococci—which are just on the limit of perceptibility, and notwithstanding endowed with motion and growth. It is plain, therefore, that the size of a living body is irrelevant in the definition of an organized individual. The smallest which we are capable of seeing with the best microscopes of to-day are granules; but we must admit that germs or particles of living matter may be present in the air or in organic fluids in infinite numbers which cannot be seen at all, and become visible only after having reached a certain size.

How complicated the structure of a minute particle of living matter may be we can hardly imagine.

The term "cell," as proposed by Schleiden and Schwann, had long been considered as a misnomer, since M. Schultze demonstrated the absence of a lining membrane and fluid contents. I have demonstrated that the so-called "cell" is not an elementary organism, but that it is composed of innumerable particles of living matter, every one of which is endowed with properties formerly attributed to the cell-organism.

According to my observations, we have not to deal with "cells" as form-elements, either in the fluids or in the tissues of the animal body, but only with living matter, varying in its appearance from the just-perceptible granule to the bulk of the body of the largest animal itself. Single lumps of living matter may show the net-like arrangement, being then termed "protoplasm;" while the body of a mammal is a continuous mass of living matter in net-like arrangement and contains fluids, in which there are suspended isolated bodies, analogous to the granules which float in the vacuoles of an amœba. The difference in the aspect of the tissues depends on the presence of a lifeless basis-substance only, a derivative of the lifeless protoplasmic fluid, while essentially all tissues are formed by protoplasm, in which living matter without interruption is united throughout the body. I may add that, according to my recent investigations, plants are built up in a way exactly corresponding to animals.

Let us give up the term "cell," as now no proper sense is connected with it; let us give the usual name to every organism, amœba, for instance, or say blood-corpuscle, pus-corpuscle, cartilage-corpuscle, etc., if we intend to designate separate lumps of protoplasm, or certain constituent parts of different tissues.

In conclusion, I may draw attention to the fact that the amount of living matter varies greatly within a limited bulk of protoplasm, both in normal and morbid conditions. The colorless blood-corpuscles of persons exhibiting signs of lymphatic, strumous, scrofulous constitution contain much less

living matter than those of strong, vigorous persons. Further examinations will in all probability teach us to make use of these differences for practical purposes. I announced three years ago that the protoplasmic lumps forming tubercle are characterized by a relatively small amount of living matter. Last year I published my observations on pus-corpuscles, which enable me, from the relative amount of living matter contained in an individual corpuscle, to say from what kind of organism such a pus-corpuscle is formed; whether the person from whom the pus comes is healthy and strong, or weakened by chronic disease, as tuberculosis.

I am thoroughly convinced that the doctrine here explained, for which Dr. Elsberg proposed the term "bioplasson-doctrine," must eventually be accepted by all judicious microscopists. The popularization of even the simplest facts takes time. Though at present objections to my observations may be raised, their correctness can never be shaken. The truth will finally triumph.